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Advances in Recycled Polyethylene Terephthalate/Polyamide 11 Hybrid Nanocomposites: A Short Review

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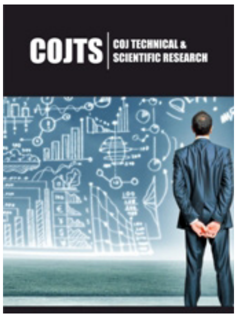

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Abstract

Recycling polyethylene terephthalate (rPET) offers significant environmental and economic benefits; However, its mechanical and thermal properties deteriorate during processing. To address these challenges, blending rPET with polyamide 11 (PA11) and reinforcing it with nanofillers such as sepiolite and graphene nanoplatelets (GNPs) were investigated. This review provides an overview of the mechanical and thermal improvements achieved by these blends and highlights the potential applications of rPET/PA11 nanocomposites. At optimal proportions of PA11 and nanofillers, improved tensile, flexural and impact strengths were observed, presenting significant prospects for industrial applications in the automotive and packaging industries.

Keywords: Recycled polyethylene terephthalate (rPET); Nanocomposites; Sepiolite nanofillers; Mechanical; Thermal properties

Introduction

Growing environmental concerns surrounding plastic waste have led to increased research into recycling polyethylene terephthalate (PET), one of the most commonly used polymers, particularly in packaging applications. Despite its advantages in terms of durability and chemical resistance, the recycling process of PET often results in a reduction in its mechanical and thermal properties, limiting its industrial reusability [1,2]. As global initiatives move towards sustainability, the development of recycled PET (rPET) blends with improved properties has become a priority [3]. A promising approach to improving the properties of rPET is blending with polyamide 11 (PA11), a bio-based polymer known for its excellent mechanical properties, low moisture absorption and superior impact resistance compared to other polyamides such as PA6 [2,4]. PA11's unique long carbon chain provides improved flexibility and durability, making it an attractive option for use in rPET blends. In addition, the incorporation of compatibilizers such as Joncryl® has been shown to improve the interfacial adhesion between rPET and PA11, further increasing mechanical performance [5]. While these blends are promising, the integration of nanofillers such as sepiolite and graphene nanoplatelets (GNPs) has emerged as a breakthrough method to further improve both the mechanical and thermal properties of rPET/PA11 composites. Sepiolite, with its large surface area and channel-like structure, facilitates improved interaction with polymer matrices, resulting in increased tensile strength and thermal stability [3,6]. On the other hand, GNPs are known for their exceptional mechanical strength and thermal conductivity, making them ideal for high-performance applications [7,8]. The synergistic effect of combining sepiolite and GNPs in rPET/PA11 matrices has not been extensively studied, making this a novel contribution to polymer science [4]. This short review article aims to highlight recent advances in the development of rPET/PA11 nanocomposites, focusing on the mechanical and thermal improvements achieved through the use of compatibilizers and nanofillers. This work presents a comprehensive analysis of the latest findings and explores the possible industrial applications of these sustainable materials.

Results and Discussion

Mechanical properties

The blending of rPET with PA11 significantly improves the tensile and impact strength of rPET, especially by adding 20% by weight of PA11. The tensile strength increased by more than 50% and the flexural strength increased from 27.9MPa to 48MPa [4,5]. This improvement is largely due to the superior properties of PA11, which is biobased and has lower moisture absorption and higher impact resistance than PA6 [9-11]. The addition of Joncryl®, a chain extender, further increased the tensile strength of rPET/PA11 blends, reaching 46.24 MPa [5].

Role of nanofillers

Nanofillers such as sepiolite and GNPs have a profound impact on the mechanical and thermal properties of rPET/PA11 composites [6]. The inclusion of 2 phr sepiolite improved the tensile strength to 41.3MPa and the flexural strength to 47.3MPa [3]. The combination of sepiolite with GNPs resulted in significant improvements: the tensile strength increased to 54.5MPa and the flexural strength reached 76.46MPa [2]. The researchers also reported that the hybrid nanocomposites also showed a significant improvement in impact strength, increasing by 83% compared to the base rPET/PA11 blend.

Thermal stability

The thermal properties of rPET/PA11 blends were significantly improved by the addition of nanofillers. Thermogravimetric analysis (TGA) revealed a 20 °C increase in the decomposition temperature of rPET/PA11 blends with nanofillers, indicating improved thermal stability [2,3]. Differential scanning calorimetry (DSC) confirmed stable melting temperatures and ensured that thermal properties remained constant during processing [6].

Morphological analysis

Scanning electron microscopy (SEM) showed a well-dispersed PA11 phase within the rPET matrix, which contributed to the improved mechanical properties. The presence of nanofillers further improved the uniformity and interaction between the polymer phases, resulting in a more robust composite structure [4,6,11].

Conclusion

The development of rPET/PA11 nanocomposites reinforced with sepiolite and graphene nanoplatelets (GNPs) represents a significant advance in the field of polymer science. This work not only addresses the environmental challenge of plastic waste through the use of recycled PET, but also improves its mechanical and thermal properties, making it suitable for high-performance applications. The incorporation of PA11 improves flexibility, impact resistance and durability, while the addition of nanofillers such as sepiolite and GNPs further increases the strength, thermal stability and overall performance of the composites. These improvements pave the way for the use of rPET/PA11 nanocomposites in industries such as automotive, aerospace and packaging, where materials with superior mechanical properties and sustainability are in high demand. The novelty of this work lies in the synergistic effect of the combination of two different nanofillers-sepiolite and GNPs-which has not yet been extensively explored. This approach shows how hybrid nanocomposites can be tailored to achieve a balance between mechanical strength and thermal performance, making them a versatile solution for various industrial applications. Furthermore, the use of Joncryl® as a compatibilizer to improve the interaction between rPET and PA11 shows an innovative way to improve recycled polymers. The significance of this research goes beyond material performance; It offers a sustainable solution by converting plastic waste into high-quality materials. Future studies should focus on optimizing nanofiller proportions and exploring other potential nanomaterials to further improve the properties of rPET/PA11 composites. Furthermore, scaling up the production of these nanocomposites for industrial use and conducting life cycle assessments (LCA) will be crucial to demonstrate their environmental and economic feasibility on a larger scale.

Future Suggestions

Further research is needed to optimize the proportion of nanofillers in rPET/PA11 blends and achieve a balance between mechanical strength and cost-effectiveness. Investigating other nanofillers such as carbon nanotubes (CNTs) or titanium dioxide (TiO_2) could lead to additional improvements in mechanical and thermal properties. Future studies should focus on scaling the production process of rPET/PA11 nanocomposites to assess their feasibility for commercial use in various industries. A comprehensive Life Cycle Assessment (LCA) of rPET/PA11 nanocomposites is required to evaluate their environmental impact and sustainability compared to conventional materials.

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